THE BIOLOGICAL THEORY OF NURTURE.

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HOROSCOPES are not much in fashion nowadays except among the undisciplined, but the problem is always with us as we look at a child. What manner of person lies there in possibility? How far is the final result already fixed, how far is the outcome an open question? Is life in some measure an unpredictable adventure?

What are the factors or influences that determine the shaping of an organism and its life? Man's case is in some measure peculiar, since he is, more or less, a rational, social person, ζῶον πολιτικόν, as Aristotle put it, and super-organic influences, such as social tradition, play upon him potently; but, biologically considered, all living creatures are subject to the same laws. For all alike there are, *sub specie vitæ*, three biological "Fates"—Heredity, Function and Environment. The influence of function and environment is technically called "Nurture" in contrast to what is implied in the inherited "Nature."

The first Fate is *Heredity*—which means the relation of genetic continuity between successive generations. The natural inheritance is all that the living creature is or has to start with in virtue of its hereditary relation. "Bless not thyself," said Sir Thomas Browne, "that thou wert born in Athens; but, among thy multiplied acknowledgments, lift up one hand to heaven that thou wert born of honest parents, that modesty, humility, and veracity lay in the same egg, and came into the world with thee." "A man," as Heine said, "cannot be too careful in the selection of his parents." Heredity, the past living on in the present, is the first Fate, and the greatest of the three.

The second Fate is *Environment*—all manner of surrounding influences that play upon the living creature, making deep dints or giving light touches, awakening some buds and frost-biting others, encouraging and depressing, training and

thwarting. Environment is the second Fate, and some of us think that it comes a better second than others of us will allow.

The third Fate is *Function*—what the creature does or does not do, the influence of use and disuse, of work and play, of exercise and rest. When we consult a book like Arlidge's *Diseases of Occupations*—a grim curiosity for future ages—we realise what an important factor function is for evil as well as good in the individual life. The importance of function as a life-shaping factor is expressed in various wise sayings: "By force of striking one becomes a blacksmith," "What you have inherited from your ancestors you must use if it is to be your very own." In the language of the immortal parable, we must trade with our talents.

Before leaving the metaphor of the three Fates, one is tempted to ask if there are not four. A swallow born and bred in Britain flies south at the end of summer, and the Aberdeen University Bird Migration Inquiry has helped to prove that such a swallow may return the following spring to the farm-steading of its birth and youth—a wonderful homing. That it can make the double journey successfully depends mainly on its inheritance, but partly on its functioning, its early training in flight, and partly on environment, *e.g.*, the nutrition which gives it strength to fly and the stimuli which pull the trigger of the migratory instinct. But is there not also a cosmic factor, quite uncontrollable by the creature itself and careless of it, which offers or withholds opportunities, which meets some migrants with a fatal storm and offers others a fair haven? Is not one of the factors in our own life a giving or withholding of opportunities which we, at any rate, have nothing to do with, which we call providence when it is with us, and chance when it is against us. But, perhaps, this is just part of our environment.

The modern idea of the biological controllability of life, perhaps dating from Darwin and Pasteur, led, not unnaturally, to an indulgence in over-sanguine hopes as to the ameliorative influences of function and environment. This was held to be demonstrable for the individual, and before the days of Galton's and Weismann's wholesome scepticism as to the transmission

of bodily modifications or individually acquired characters, it was often held to be true as regards the race. But a strong reaction has set in. Let us briefly consider why.

(1) If we take the eggs of, say, the blackheaded gull and hatch them in an incubator in the laboratory, and rear the results in confinement, we get, as everyone knows, a number of normal, well-endowed young birds, which will migrate months afterwards when their kinsfolk fly about overhead. The environment, the whole nurture, was very peculiar, but it did not seem to make much difference. There is evidence, indeed, that birds which have not known freedom are badly handicapped when liberated, because they do not know their way about. But the clear fact seems to be that for many creatures changes of nurture do not fundamentally matter as long as the essential conditions of life are not interfered with. The full inheritance may not be expressed, but a large proportion of it is realised as usual. There are many delicate creatures, such as the larvæ of sea-urchins, which are difficult to rear, which do not readily stand even slight nurtural changes, but many other creatures can within limits adjust themselves to, and develop normally in quite peculiar conditions of life. It is a very striking fact that the ovum of a rabbit can develop for two days normally outside of the body, and Man is peculiarly master of his Fate. What then is the importance of nurture?

(2) It is likewise a familiar fact that there is often an extraordinary tenacity in the persistence of hereditary characters, no matter how the nurture is changed. Having all the fingers thumbs has been known to persist for six generations, night-blindness in a lineage for two and a half centuries, a particular kind of dwarf for four generations. A peculiar variety of the Greater Celandine with cut-up leaves which appeared suddenly in an apothecary's garden at the end of the 16th century has bred true ever since. "He that will to Cupar maun to Cupar," we sadly say in Scotland. "Each man's nature is his fate," said Democritus, and the modern students of heredity agree. What then is the importance of nurture?

(3) Another consideration is this. It is not difficult to impose peculiarities on organisms by subjecting them to peculiarities of

nurture. A goldfish kept continuously in the dark becomes quite blind; caterpillars subjected to cold may turn into dark-coloured butterflies; birds, such as the bobolink, may be dieted so that they keep their breeding plumage through the year and will sing their spring song in mid-winter. These are three instances out of three hundred instances of the power of nurture, to which we shall return. But everyone knows that we cannot assert that any one of these extrinsic modifications is as such, or in any representative degree, entailed on the next generation. So what is the importance of nurture?

(4) We have the statistical evidence furnished by Professor Pearson and the Galton Laboratory—which leads to the important conclusion that the results of changes in nurture are of relatively small importance compared with the results of variation in the physique, the mentality and the habits of parents—that "the degree of dependence of the child on the characters of its parentage is ten times as intense as its degree of dependence on the character of its home or uprearing." "It is five to ten times as profitable for a child to be born of parents of sound physique and of brisk, orderly mentality as for a child to be born and nurtured in a good physical environment."

Having given four reasons which warrant us in regarding the first Fate—Heredity—as fundamental, let us state some of the reasons for continuing to attach great importance to Nurture. I regret that I have no statistics to offer nor experiments of my own to which to refer; but I venture to think that what I have to say would be subscribed to by all well-informed biologists as a fair statement of the biological theory of nurture. Professor Pearson has emphasised the importance of the inherited nature, and I agree; my aim is to emphasise the importance of nurture.

I. I would say first that since both are indispensable there is no antithesis. As one of the leaders of the experimental study of heredity—Professor T. H. Morgan—has recently said:[1] a "character is the product of a number of genetic factors and of environmental conditions"; or, again, "every character is

[1] T. H. Morgan and others: The Mechanism of Mendelian Heredity. New York 1915.

the realised result of the reaction of hereditary factors with each other and with their environment"; or again, "it is a commonplace that the environment is essential for the development of any trait, and that traits may differ according to the environment in which they develop."

We have admitted that the strength of an (inherited) individuality may be such that it expresses itself almost in the face of inappropriate nurture, but there is a minimum nurture necessary if there is to be development at all, and the conditions of nurture determine whether the expression of the inheritance is to be full or partial, abundant or stunted, or it may be, as regards a particular feature, absent altogether.

Gudernatsch has shown that in tadpoles fed on thyroid there is differentiation without growth, while in tadpoles fed on thymus and spleen there is growth without differentiation.[1]

A character known to be part of the inheritance may remain entirely unexpressed in the individual development because certain environmental conditions are lacking, yet the heritable character may be handed on all the same.

Fruit-flies *(Drosophila)* of a Mendelian race with a peculiar abnormality may appear perfectly normal if raised in a dry bottle, but the presence within them of the "factor" for abnormal may be demonstrated by rearing their offspring in a wet bottle.[2]

A diagrammatic illustration of my point concerns the red Chinese primrose (*Primula sinensis rubra*). Reared at 15-20° it has red flowers; reared at 30-35° C., with moisture and shade, the same plants have pure white flowers. The development, so far as colour goes, depends on its nurture.[3]

Take another illustration from the Fruit-fly. There is a mutant stock that produces supernumerary legs, a considerable percentage in winter, few or none in summer. Miss Hoge finds that when the flies are kept in an ice chest at a temperature of about 10° C., a high percentage of flies with supernumerary legs occurs. In a hot climate there would be no evidence that

[1] Amer. Journ. Anat., XV. (1914), pp. 431-78, 2 pls.
[2] T. H. Morgan and others, op. cit. p 47.
[3] Ibid., op. cit. p. 38.

the peculiarity was part of the inheritance; in a cold region it would be obvious. This shows that the expression of the inheritance as regards a particular character sometimes depends on nurture.[1]

In the dark caves of Dalmatia lives the well-known blind salamander Proteus, nearly a foot long, with a white skin, a little pinkish because of the blood. Its white skin is like a photographic plate, as Dr. Gadow put it, for if there is the least light it becomes spotted with grey patches, and in diffuse light it becomes black. The newly-hatched descendants of these dark parents are also dark, but this is probably because the light gets through the body of the parent, and influences the eggs before they are laid. In any case, it depends on nurture whether a Proteus is white or black.

II. While some developing organisms are strikingly indifferent to changes in their environment, there are others which respond sensitively, sometimes in a startling way, to changes which do not seem very drastic. MacDougal's well-known experiments[2] of injecting solutions of sugar, calcium, potassium, and zinc into the developing ovaries of one of the Evening Primroses resulted in a small percentage of notably atypical individuals, which bred true to the third generation. The chemical reagents introduced were not very different from those which might occur naturally in the sap of the plant. Among the changes induced there were not only losses and augmentations of what was previously present, there were distinct novelties which maintained their distinctness when crossed with the parental strains.

Loeb[3] has recently shown that it is very easy to produce a percentage of fish-embryos *(Fundulus)* with defective eyes by adding a minute quantity of potassium cyanide to the water or by exposing the newly fertilised eggs to low temperature. That is to say, relatively slight environmental changes may so alter the constitution of the developing embryo that a leap is taken in the direction of blindness.

[1] Morgan op. cit. p. 41.

[2] In lecture on "The Direct Influence of Environment" in "Fifty Years of Darwinism" (1909).

[3] Biol: Bulletin xxix, 1915, p. 50.

Similarly Stockard[1] has shown for the same fish that the addition of a very minute quantity of magnesium salt to the water induces in a large number of them the development of a single Cyclopean eye in place of the normal two eyes.

Such cases are to be borne in mind in connection with man and mammals where even slight extrinsic or exogenous changes in the blood of the mother may affect the development of the unborn offspring living in intimate symbiosis with her. It is very important to realise the difficulty of distinguishing between what is due to inherited nature and what is due to some peculiarity in ante-natal nurture.

The effect of negative nurture on the individual is sometimes very remarkable. It is well known that certain simple worms (Planarians) can be starved for months without fatal effects. They become smaller and smaller, living on their own internal resources. Some of their cells disappear altogether and others are greatly reduced in size. This is an old story, but Professor Child has recently shown that the reduction in size is associated with a remarkable rejuvenescence, and that the vital processes are quickened. The starveling becomes young again—surely a quaint biological justification of asceticism. Many similar facts are given in Child's recently published book on "Senescence and Rejuvenescence."[2]

And what is true of nutrition is true of other factors in nurture; they alter the punctuation of the life-cycle. A herring's egg in the sea hatches in a little over a week; put it in a refrigerator, and the development is slowed down so that the egg takes fifty days to hatch.

III. Without assuming that a peculiarity of the body, acquired as the direct result of a peculiarity in nurture, can be as such or in any representative degree entailed on the offspring, of which there is no convincing proof, we may recognise that nurture may be of considerable importance to the race. The modification may give the individual a life of conspicuous success or failure, which may result in a subsequent increase or decrease in the numbers of the type which it represents, thus obviously working for both good and ill to the race. Vigour acquired

[1] Journ. Exper. Zoology, February, 1909.
[2] Chicago, 1915.

by open-air exercise gives a man resisting power against infection; it may keep bad constitutions alive; it will also keep good constitutions from being gratuitously weakened. Reduction of the likelihood of infection will also work both ways.

It has often been pointed out that an individually acquired modification may serve as a life-saving screen until an innate variation with similar result has time to establish itself. Thus artificial immunity may be a useful temporary modification until natural immunity arrives—if it does arrive.

In the case of mammals the unborn offspring may be damaged by the ill-nourished, over-strained, or poisoned state of the maternal body. There is not transmission of acquired characters in the technical sense, but there is antenatal deterioration and arrestment of the offspring as the result of abnormal nurture on the parent's part. Some evidence exists which goes to show that deeply-saturating parental modifications, such as the results of poisoning, may affect the germ-cells. The influence very probably affects the cytoplasm rather than the chromosomes.

There is little likelihood that we are at an end of the question as to the possible effect of modifications (nurture-effects) on inheritance, and a useful hint of the subtlety of the problem may be got from a brief consideration of the most important British investigation on the subject—Dr. Agar's study[1]—of a water-flea (*Simocephalus*), a little crustacean with two valves. Under certain nutritive conditions the crustaceans acquired a peculiar reversal of their shell-valves, doubtless as the result of altered metabolism. After the eggs had appeared and grown in the ovary the animals were restored to normal conditions. In due time the eggs developed into forms with reflexed shell-valves such as their parents had acquired. Later on, however, when the parents laid again the abnormal effect was seen only to a very slight degree, and in a third brood it had dwindled away. The probability is that the abnormal nurture resulted not in any disturbance of the inheritance, but in the formation of some peculiar non-living metabolic product, which was included in the cytoplasm of the egg, passed

[1] Phil. Trans. Series B. cciii. (1913) pp. 319-50.

passively into the body which developed from the egg, and there produced on the body of the offspring the same effect as it originally produced on the body of the parent which acquired the character in question.

In this connection reference may be made to a view sketched by an ingenious French biologist, Bohn. In one aspect the organism is a vast system of correlated chemical processes. There are numerous main lines of metabolism which work together. If conditions demand it, there may be a great local increase along any one of these lines, just as in the activities of a country. Thus, hard exercise of the limbs may induce unusually intense myogenic metabolism—the making of muscle substance. This is seen in the professional dancer for instance. But because of correlation—a fact imperfectly understood—the myogenic fashion, so to speak, spreads, and affects other parts of the body, such as the dancer's heart. Now it may be that although the germ-cells remain unaffected by any particular muscular modification, they may be specifically affected by a general dominance of myogenic metabolism.

Very striking and suggestive are Professor Child's experiments on the effect of altered diet on Planarian worms.[1] Thus a diet of freshwater mussels depresses the vitality, *i.e.*, lessens the rate of metabolism and the power of resistance. The stock becomes senescent, and if the diet be continued for several generations there is an aggravation of senescence, for they begin to be born old. The effect of the mussel diet is cumulative. One does not dream of arguing from worm to man, but one recognises the importance of competent experiments which show that the course of the life-cycle may be greatly altered by changing the character of the food.

Bordage made some interesting observations on European peach trees transported to Réunion. As has been noticed in similar cases, they dropped their deciduous habit and became—it took some of them twenty years—evergreen. The individual constitution was altered. Still more interesting was the fact that when seeds of these pseudo-evergreens were sown in certain mountainous districts with a considerable amount of frost, they pro-

[1] "Senescence and Rejuvenescence" 1915.

duced young peach trees which were also evergreen. European seeds sown in similar places produced ordinary deciduous trees. It is probable that the apparent inheritance in the case of the peach trees was the result of an influence on the body of the seed before it was separated from the parent. A similar result in mammals may be readily confused with inheritance.

IV. There is an increasing body of facts pointing to the conclusion that changes in nurture may serve as variational stimuli, that is to say that they may affect the germ-cells through the parent, so that a variation occurs in the offspring. Thus, Professor Tower subjected potato beetles, at a certain stage of their development, to unusual conditions of temperature and humidity. The body of the beetles exhibited no modification, and that was not to be expected. But in a number of cases the offspring of these beetles showed remarkable changes in colour and markings, and even in minute details of structure. And there was no reversion to the parental condition. It looks as if a peculiarity in the environment might serve as a liberating stimulus to variability.

Just in a sentence let me refer to the probability that much may depend upon the nurtural reception that a natural variation meets with. Unless the nurture evolves progressively along with the nature, *in mankind especially,* many new departures may be blocked at the outset, many promising variations may be born only to die.

On no account whatsoever are we to countenance, if we can help it, spoiling good stock by bad; but it is a dubious inference that the bad is hopeless. It may often be that it is not so bad as it looks. In her interesting study, "Environment and Efficiency,"[1] Miss Mary Horner Thomson tells of her study of 265 children, mostly of "the lowest class" (Class A, fourth below the poverty level!), who had been sent to institutions and trained. She found that 192 (72 per cent.) turned out well; that 44 (16 per cent.) were doubtful; and that only 29 (less than 11 per cent.) were unsatisfactory, and of these 13 were defectives. These figures, which should be checked and multiplied, afford some evidence of the controllability of life.

[1] Longmans, 1912.

IN CONCLUSION. Illustrations have been given of a number of facts:—that nurture is important as a condition of normal development; that on its richness in liberating stimuli the degree of development in part depends; that even a slight change in nurture may mean a great deal; that in mammals especially it is not always easy to distinguish what is in the strict sense inherited from what is due to ante-natal nurture; that nurtural effects though not transmissible may be in several ways of indirect racial importance. It has also been pointed out that there are some facts suggesting the theory that peculiarities of nurture may act as variational stimuli—tending to the emergence of the new.

It would be quite fallacious to argue from any of the illustrations I have given to man, but, perhaps, I have said enough to suggest the undesirability of losing faith too utterly in the potency of nurture in shaping the individual life. Of the danger of arguing from one case to another, let me give an interesting illustration concerning the influence of alcohol. D. D. Whitney studied the effect of minute traces of alcohol in the water in which Rotifers or wheel animalcules were kept. The result was a decrease in reproductive power and a weakening in the power of resistence to deleterious influences. Twenty-eight generations were studied and the evil effects of the alcohol were proved. But from the eleventh to the twenty-second generation at least it was found that removal of the alcohol was followed by rapid individual recovery, and that the grandchildren showed none of the defects caused by alcohol in their grandparents.

Stockard subjected male guinea-pigs for three years to vapours of alcohol, which does not spoil their stomach, and found that an alcoholised male guinea-pig almost invariably begets defective offspring even when mated with a vigorous normal female. The effects were manifest in the second generation also. "The poison injures the cells and tissues of the body, the germ-cells as well as other cells, and the offspring derived from the weakened or affected germ-cells have all the cells of their bodies defective."

In previous attempts to appreciate the importance of nurture for the individual I have laid emphasis on its rôle in the development of the human mind, and for this I have been severely taken to task. If I have erred, it is in company with many biologists and psychologists of high standing who have declared that our mind is in large measure a social product. One of the sanest of them, Professor G. H. Parker, writes : " our intellectual outfit comes to us more in the nature of a social contribution than an organic one." While our mental capacity is primarily determined by heredity, it can be encouraged and augmented, or inhibited and depressed, within wide limits, by nurture.

Especially as regards the mind, do we feel that while the inheritance is the seed-corn, " nurture " is the soil and the sunshine, the wind and the rain. Nurture can create nothing, but without it the buds that are there may fail to open or to unfold freely or to blossom. We cannot make a silk purse out of a sow's ear, but by trading with our talent we may make it two, or peradventure five talents.